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HEALTH HAZARDS IN DUSTY TRADES.

In studies made of the health hazards in abrasive industries, it has generally been assumed that the mineral particles from the abrasive material itself are as important a factor as the metallic dust from the object subjected to the grinding or polishing treatment. And yet, heretofore, little attention has been given to the health hazard in the manufacture of the abrasive materials themselves. The following paper gives the results of careful studies of conditions in two large factories where abrasive materials are manufactured.

THE DUST HAZARD IN THE ABRASIVE INDUSTRY.

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Incidence of Tuberculosis among Workers Exposed to Mineral and Metallic Dusts.

The conviction is growing, among students of industrial hygiene, that the incidence of tuberculosis among the workers in dusty trades is one of the gravest problems in this field.

The ideal basis for estimating the seriousness of industrial tuberculosis would be an analysis of actual death rates classified by age at death and by occupation. Unfortunately, data of this kind are practically nonexistent in the United States. A reasonably close approximation to the truth may, however, be obtained by a study of the ratio between tuberculosis deaths and deaths from all causes, ignoring the population exposed which is the unknown element in the problem. A low ratio of tuberculosis deaths (such as is found in the case of railroad employees) may not, of course, indicate a real freedom from tuberculosis but rather a special exposure to some other hazard. A high tuberculosis ratio on the other hand is almost always significant of an excessive death rate from this disease, since most of the factors which promote tuberculosis are of such a nature as to increase mortality from other causes as well.

Two important studies of tuberculosis ratios by industries and age periods have been made in this country—one by the United States Bureau of the Census for the Registration Area in 1908, and

1909, and the other by Mr. F. L. Hoffman for the Prudential Insurance Co. of New Jersey. The whole subject has recently been reviewed by Mr. Hoffman in a very valuable bulletin, No. 231, United States Department of Labor.

The census figures cover a comparatively small number of rather loosely defined occupations; and the Prudential figures, while superior from the standpoint of occupational classification, are open to two other objections. In the first place many of the figures cited by Mr. Hoffman are based on such small numbers of cases as to involve large errors of random distribution. In the second place the ratios calculated for the insured populations are obviously affected by factors of special selection so that they are not fairly comparable with data obtained from other sources.

This constant difference between the Prudential figures and the census data is clearly brought out in Table I, which we have compiled from the tables in Mr. Hoffman's bulletin so as to include all the industries exposed to metallic or mineral dusts for which 500 or more deaths from all causes at all ages were available. It is evident that in almost every instance where the two series can be compared the Prudential ratios are from 25 to 50 per cent higher than those for the registration area.

TABLE I.—*Ratios, in per cent, of tuberculosis deaths to total deaths in occupations exposed to mineral and metallic dusts.*[1]

Occupation.	United States registration area.						Prudential experience.					
	Ages.						Ages.					
	15-24	25-34	35-44	45-54	55-64	15 and over.	15-24	25-34	35-44	45-54	55-64	15 and over.
All occupied males	28.1	30.9	24.0	14.4	7.6	14.9	33.2	40.9	32.9	19.0	8.8	20.5
Brick, tile, and terra cotta workers	......	......	......	......	......	......	22.9	35.3	19.8	18.6	10.7	15.6
Iron and steel workers	19.8	26.1	23.3	16.7	8.5	16.9	30.0	34.1	31.3	14.7	8.7	21.0
Plasterers	25.0	31.5	34.5	16.4	7.8	16.7	34.5	43.6	40.4	23.5	11.8	21.9
Molders	......	......	......	......	......	......	23.7	40.4	30.7	21.6	13.9	23.0
Paper hangers	......	......	......	......	......	......	35.1	44.0	42.5	15.7	11.5	29.1
Painters, glaziers, and varnishers	30.8	36.9	29.2	17.4	9.0	18.7	......	......	......	......	......	......
Tinplate and tinware workers	39.4	36.7	34.8	13.7	6.6	18.7	......	......	......	......	......	......
Jewelers	50.0	39.7	23.4	14.1	8.5	17.8	50.9	58.3	45.3	21.2	11.1	29.3
Glassblowers	......	......	......	......	......	......	45.1	53.3	31.3	28.3	15.4	32.1
Other glassworkers	......	......	......	......	......	......	31.5	51.1	34.4	23.1	15.5	30.5
Glassworkers	47.2	42.6	33.1	19.7	7.9	30.0	......	......	......	......	......	......
Tool and instrument makers	......	......	......	......	......	......	37.5	52.7	36.9	33.7	10.4	31.9
Potters	......	......	......	......	......	......	31.2	49.6	39.8	30.2	21.1	32.2
Marble and stone cutters	26.2	43.5	44.1	41.6	23.3	30.7	38.3	53.1	44.4	39.0	26.7	33.6
Brass workers	......	......	......	......	......	......	58.2	51.0	43.8	24.2	16.1	30.7
Compositors and type setters	......	......	......	......	......	......	46.3	55.9	41.1	24.9	9.8	36.8
Pressmen	......	......	......	......	......	......	42.9	47.7	44.0	20.0	11.1	39.6
Printers, lithographers, and pressmen	43.6	50.0	36.3	21.5	7.7	29.5	......	......	......	......	......	......
Polishers	......	......	......	......	......	......	43.4	56.1	44.0	24.9	14.3	36.8

[1] Figures taken from Bulletin No. 231, Bureau of Labor Statistics, U. S. Department of Labor.

It seems evident that a comparison between the Prudential figures for a given dusty trade and the census figures for all occupied males is not a fair one and that the conclusion (indicated by such a comparison) that such groups as the iron and steel workers experience an excessively high death rate from tuberculosis is unwarranted. As a matter of fact, comparisons made in each case with the corresponding group (census figures for a dusty trade with census figures for all occupied males, or Prudential figures for a dusty trade with Prudential figures for all occupied males) show that the tuberculosis ratio for the iron and steel workers is about normal, which is what should be expected for so diversified an occupational group.

With the precaution of using in each case a proper basis of comparison, both the census and the Prudential data are highly illuminating and bring out very clearly the excess of tuberculosis in certain occupations. The two sets of figures (allowing for the constantly higher ratios throughout the Prudential experience) check each other very closely, even to such special points as the very high incidence among jewelers under 35 and among marble and stone cutters over 35 years of age.

In general the data show quite clearly that exposure to mineral and metallic dusts, as among brass workers, marble and stone cutters and polishers, is accompanied by tuberculosis ratios at least one-third greater than the ratio for all occupied males, and at some age periods more than twice as great. What this means in terms of actual death rates may be estimated from Table II, based on English data which indicate that a tuberculosis ratio half again as high as the normal corresponds to an actual mortality from tuberculosis of one to two persons per thousand in excess of the mortality among all occupied males. In other words, one or two out of every thousand persons in these dusty trades are sacrificed each year to the special hazards of their employment.

TABLE II.—*Death rates, and ratios in per cent, of tuberculosis deaths to total deaths, in industries exposed to metallic dusts in England and Wales, 1900–1902.*

Age at death.	All occupied males.			Occupations exposed to metallic dusts.		
	Deaths per 1,000.		Per cent due to tuberculosis.	Deaths per 1,000.		Per cent due to tuberculosis.
	Total.	Tuberculosis.		Total.	Tuberculosis.	
15–19	2.44	0.54	22.1	2.73	0.73	26.7
20–24	4.41	1.55	35.1	5.28	2.73	51.7
25–34	6.01	2.03	33.8	6.29	3.33	52.9
35–44	10.22	2.74	26.8	11.68	5.05	43.2
45–54	17.73	3.04	17.1	20.97	5.22	24.9
55–64	31.01	2.16	7.0	36.03	3.91	10.9
65 and over	88.39	1.11	1.3	95.52	1.54	1.6

The Hazard of Industrial Tuberculosis in the Abrasive Industry.

Statistical analyses and special intensive and experimental studies alike have shown that the most hazardous of the dusty trades are those in which the workers are exposed to the inhalation of small, hard, sharp, nonabsorptive particles. The continued inhalation of metallic and silicious particles first of all initiates a fibrosis, which is the primary reaction to their deposition in the lung tissues, and then leads, in a majority of cases, to the development of pulmonary tuberculosis in the injured organ.

Among the various types of workers liable to industrial tuberculosis, grinders and other users of abrasive materials are recognized as being among the worst sufferers; and it has generally been assumed that the mineral particles thrown into the air from the abrasive material itself are as important factors as the metallic dust from the object subjected to the grinding or polishing treatment. Yet, curiously enough, so far as we are aware, no one has hitherto called attention to the peculiar hazard which menaces the workers engaged in the manufacture of the abrasive materials themselves.

The inorganic fraction of the dust in the air of the abrasive factories studied by the writers includes at least four different materials—coke, crude aluminum hydroxide, a fused aluminum compound (aloxite or alundum), and carborundum. The exact harmfulness of coke dust is not yet fully determined and the crude aluminum hydroxide is made up of softer and more rounded particles than the carborundum or the fused aluminum compounds. The last two types of material may for practical purposes be considered to possess the same physical properties. Both derive their chief value from their hardness, which is between 9 and 10, carborundum being said to approach very closely in hardness to the diamond. In addition to this property, these materials also possess the property of fracturing in very irregular particles. We have examined many specimens of these dusts and found them to be exceedingly hard, exceedingly sharp, and made up to the extent of 95 to 100 per cent of inorganic material.

Photomicrographs of several samples of these dusts submitted in Plate 1 illustrate in the main the characteristics referred to.

We have every reason to expect from analogy with other industries in which workers are exposed to a similar hazard, that dusts of this nature should be exceedingly deleterious to health. The results of a study of air dustiness in two large abrasive factories where grinding wheels, or materials for grinding wheels, are manufactured, may therefore be of value in calling attention to a hitherto neglected hazardous industry.

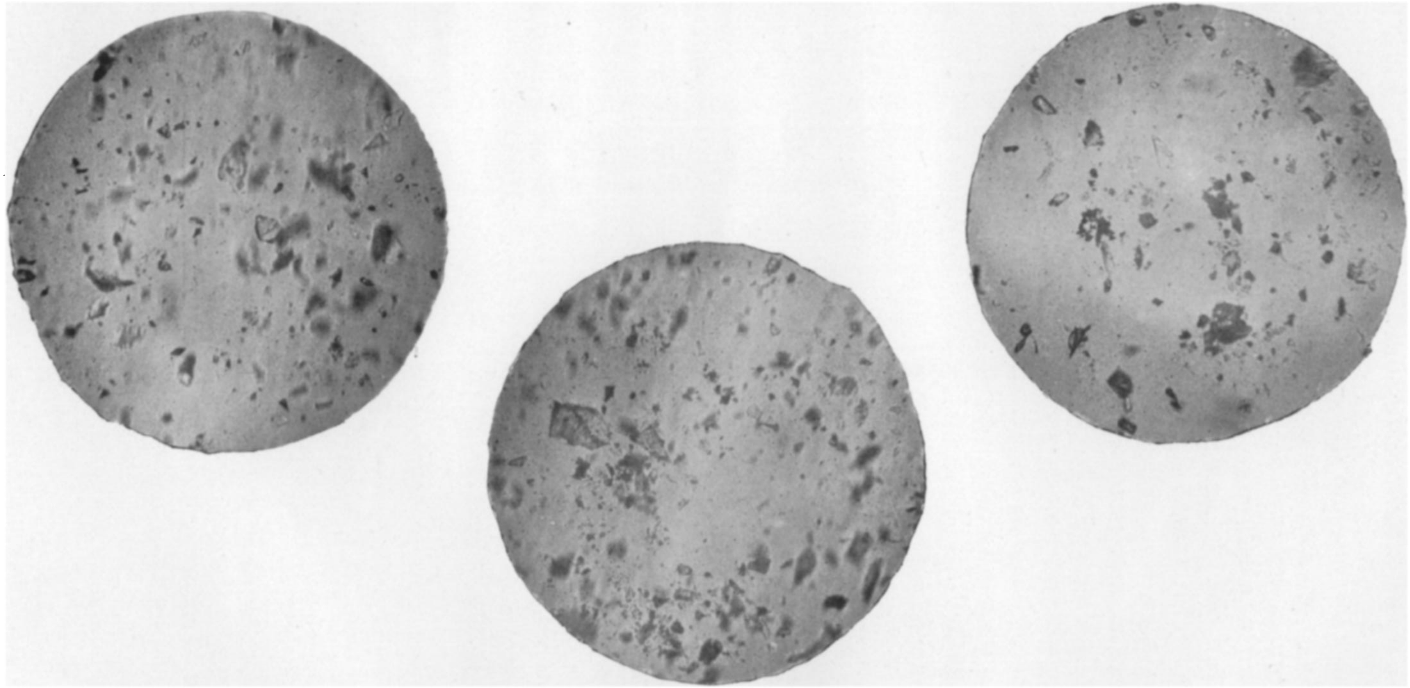

PLATE 1.—PHOTOMICROGRAPHS OF DUST SAMPLES FROM FACTORY B. MAGNIFICATION, 135 DIAMETERS.

General Conditions as Regards the Dust Hazard in Abrasive Factory B.

The first of the abrasive establishments studied, which will be referred to as factory B, is a large plant, which in the summer of 1918 employed 2,000 hands, of whom about 400 were women. The carborundum, of which the wheels are made, is prepared by heating a mixture of coke, sand, salt, and sawdust in the electric furnace. The carborundum is then ground, sifted on jiggers and molded (pressed) to form the wheel. In another department aloxite wheels are made by puddling, and after the wheels are puddled and dried they are submitted to a process known as "shaving." The wheels of either type are kilned and finally smoothed on lathes. The process of shaving is an exceedingly dusty one and probably could be effectively controlled only by carrying it on in some form of inclosed cabinet similar to that used in sandblasting. The mixing and the lathing processes are also very dusty, but it should be possible to maintain reasonably good conditions in both cases by the use of inclosed machines in the mix room, and by powerful local exhaust in connection with the lathes.

In the carborundum department of factory B practically no precautions had been taken last summer in either of these workrooms, while in the aloxite department the "new grinding room" was provided with inclosed machinery, and the lathes in the "new lathe room" were equipped with an exhaust system which the management believed to be adequate. A careful examination of the system showed, however, that it was gravely defective in a number of respects. Its principal shortcomings may be profitably cited because they are typical of conditions which are frequently noted in the inspection of exhaust systems designed or operated by those who are unfamiliar with the principles of efficient dust removal.

1. The exhaust ducts were so small that their high frictional resistance greatly increased the cost of operation and made it very difficult to maintain an adequate suction pressure. Furthermore, such small pipes tend to clog with lint and dust, and dealing with the latter tendency was made doubly difficult because an insufficient number of clean-out handholes was provided.

2. The system as installed had been allowed to deteriorate seriously for lack of careful maintenance. Many ducts were noted with broken joints. The dust separators in some cases were in very bad condition, large holes being plugged only with rags and waste.

3. Partly as a result of conditions noted under (1) and (2) or, to look at it in another way, due to the lack of sufficient fan capacity to overcome these limitations, the suction pressure in the exhaust system was far too low to be effective. With the exception of the ducts serving certain of the shaving hoods this pressure never exceeded that of a 1-inch water gauge.

4. Finally, the hoods for removing the dust from the immediate vicinity of the machines were defective in design. Such hoods should be so arranged as to apply as large a fraction as possible of the suction velocity in the exhaust pipes to the dust at its point of formation, and the suction should preferably be applied from such a direction as to take advantage of the tangential momentum imparted to the dust as it leaves the wheel. Instead, we found most of the machines entirely lacking hoods, the exhaust duct merely terminating in a funnel-shaped opening below the center of the machine spindle so far away that the velocity of the exhaust was scarcely perceptible at the face of the wheel.

Dust Content of Air in Abrasive Factory B.

The actual conditions existing in this factory at the time of our visit are indicated in Tables III–VIII, the general results of all observations in the production departments of the factory being presented in detail in Table III and the data for each workroom separately in Tables IV–VIII. The methods used in this study have been fully described in a paper by Winslow, Greenburg, and Angermyer on Standards for Measuring the Efficiency of Exhaust Systems in Polishing Shops (Public Health Reports, Mar. 7, 1919). They are essentially those recommended by the committee on standard methods for the examination of air of the American Public Health Association (American Journal of Public Health, VII, 54).

TABLE III.—*Dust content of air and per cent of inorganic solids in abrasive factory B.*

Sample number.	Sampling position.	Number of particles per cu. ft. of air, classified by size in standard units.			Total number of particles per cu. ft. of air.	Standard units per cu. ft. of air.	Weight of solids, mgs. per cubic foot of air.			Per cent of inorganic solids.
		10 Std. u.	1 Std. u.	¼ Std. u.			Total.	Organic.	Inorganic.	
	Old lathe room:									
8131	Center	....	42,500	2,724,000	2,766,500	723,500	0.57	0.02	0.55	96.5
8132	North end	5,560	56,800	3,625,000	3,687,300	1,018,700	.48	.03	.45	93.7
8133	South end	5,560	77,800	2,134,000	2,217,300	666,900	.38	.03	.35	92.0
8141	Edging machine	....	....	1,400,000	1,400,000	350,000	.11	.01	.10	91.7
8142	Do	7,135	14,270	2,091,000	2,112,400	608,800	.23	.01	.22	95.6
8143	Do	....	3,300	7,415,000	7,418,300	1,857,000	.64	.01	.63	98.3
8144	Do	....	53,100	2,870,000	2,923,100	770,600	.51	.01	.50	98.0
8145	Facing machine	....	53,100	5,950,000	6,003,100	1,540,600	.99	.01	.98	99.0
8146	Do	14,820	237,000	17,200,000	17,451,800	4,685,000	4.09	.02	4.07	99.5
	New lathe room:									
8151	Facing machine	....	333,500	17,500,000	17,833,500	4,708,500	2.64	.03	2.61	98.8
8152	Edging machine	....	51,800	2,785,000	2,836,800	748,000	.37	.03	.34	92.0
8153	Do	....	44,500	3,702,000	3,746,500	970,000	.72	.01	.71	98.6
8154	Do	....	22,200	2,960,000	2,982,200	762,200	.37	.01	.36	97.4
8161	Facing machine	....	44,500	7,515,000	7,559,500	1,923,300	1.79	.01	1.78	99.4
8162	Do	....	185,000	4,900,000	5,085,000	1,410,000	1.40	.01	1.39	99.0
8163	Do	....	118,500	1,869,000	1,987,500	585,800	1.18	.02	1.16	98.3
	Shaving room:									
8191	Shaving machine	59,300	267,000	72,100,000	72,426,300	18,885,000	1.78	.13	1.65	92.7
8192	Do	60,000	393,000	181,000,000	181,453,400	46,247,000	6.62	.39	6.23	94.0
8193	Facing machine	....	59,300	15,900,000	15,959,000	4,034,300	.36	.02	.34	94.5
8194	Do	....	118,500	15,590,000	16,068,500	4,106,000	.47	.04	.43	91.5
8195	Shaving machine	29,600	356,000	176,500,000	176,885,600	44,777,000	3.97	.22	3.75	94.4
8196	Do	59,200	296,000	222,500,000	222,855,200	56,513,000	5.48	.32	5.16	94.1

TABLE III.—*Dust content of air and per cent of inorganic solids in abrasive factory B*—Continued.

Sample number.	Sampling position.	Number of particles per cu. ft. of air, classified by size in standard units.			Total number of particles per cu. ft. of air.	Standard units per cu. ft. of air.	Weight of solids, mgs. per cubic foot of air.			Per cent of inorganic solids.
		10 Std. u.	1 Std. u.	1/4 Std. u.			Total.	Organic.	Inorganic.	
	Mix building:									
8201	Basement	88,800	2,635,000	148,800,000	151,523,800	40,723,000	6.23	1.09	5.14	82.5
8202	Do	22,200	111,200	53,500,000	53,633,400	13,708,200	1.49	1.46	.03	2.0
8211	Coke grinder	30,500	794,000	12,260,000	13,084,500	4,164,000	2.62	2.51	.11	4.2
8212	Scales	29,900	823,000	67,100,000	67,952,900	17,897,000	2.26	.94	1.32	58.4
	Grinding room:									
8213	Pan mill	......	133,500	584,000	717,500	279,500	.....	.....	.....	.....
8221	Do	14,800	185,000	3,200,000	3,399,800	1,133,000	.62	.12	.50	80.6
8222	Yard	7,400	296,000	5,190,000	5,493,400	1,667,500	.92	.12	.80	87.0
	Grinding room:									
8223	Pan mill	14,800	370,000	8,290,000	8,674,800	2,590,500	1.05	.27	.78	74.3
8224	Do	......	400,000	16,100,000	16,500,000	4,425,000	.95	.17	.78	82.1
8225	Elevator	14,800	414,000	32,500,000	32,928,800	8,687,000	3.27	.69	2.58	78.8
8226	Yard	7,400	118,500	2,915,000	3,040,900	921,200	.24	.10	.14	58.4
	New grinding room:									
8231	Crusher	29,600	680,000	23,800,000	24,509,600	6,926,000	5.63	.03	5.60	99.4
8232	Do	14,800	44,400	11,500,000	11,559,200	3,067,400	2.90	.01	2.89	99.6
	New lathe room:									
8233	East end	600	12,400	202,000	215,000	68,800	.18	.01	.17	94.8
8241	Center	......	340,000	9,910,000	10,250,000	2,817,500	.81	.01	.80	98.5
8242	West end	......	22,200	1,135,000	1,157,000	305,900	.17	.01	.16	94.0

TABLE IV.—*Dust content of air, and weight of dust in mgs. per 100 cubic feet of air in the old lathe room, factory B.*

Sample number.	Sampling position.	Total number of particles (10 microns and under) per cubic foot of air.	Weight of dust, mgs. per 100 cubic feet of air.
8131	Center of lathe room	2,724,000	57.0
8132	North end of lathe room	3,635,000	48.0
8133	South end of lathe room	2,134,000	38.0
8141	Edging machine	1,400,000	11.0
8142	.....do	2,091,000	23.0
8143	.....do	7,415,000	64.0
8144	.....do	2,870,000	51.0
8145	Facing machine	5,950,000	99.0
8146	.....do	17,200,000	409.0

Table IV shows the conditions in regard to air dustiness which existed in the so-called "Old lathe room," in which the carborundum wheels are trimmed to finished dimensions. Almost no measures were taken for the protection of the worker, such exhaust ducts as were present being badly designed, and the suction head, in four cases in which it could be measured, varying between 3/8 and 1 3/8 inches. Samples were taken at various machines in this room—at those in which the smallest as well as largest wheel was worked—in order to obtain a representative group of samples. It may be pointed out that these samples were taken as close to the operator, and as nearly at the breathing level, as conditions permitted without interfering with

the work. It appears from this table that the amount of dust varied from 11 to 409 mgs. per 100 cubic feet, and that the microscopic counts of particles (10 microns and under) numbered from 1,400,000 to 17,200,000 per cubic foot of air. On this basis it is easy to calculate in a general way the amount of dust breathed by an individual in a given period of time. Assuming the tidal air of man to be 30.5 cubic inches, and the respiratory rate 17 per minute, then the amount of air breathed per minute will be 518 cubic inches, or 100 cubic feet in 333 minutes (slightly more than 5½ hours). For example, the amount of dust breathed by the worker at the machine at which sample 8146 was taken amounts to 409 mgs. in 5½ hours.

The presence of such large amounts of dust produced a condition of air dustiness which was not confined to the immediate vicinity of the machines, but extended throughout the whole workroom. Samples 8131, 8132, and 8133, taken at points in the lathe room well removed from the machines, illustrate this fact.

TABLE V.—*Dust content of air, and weight of dust in mgs. per 100 cubic feet of air in the new lathe room, factory B.*

Sample number.	Sampling position.	Total number of particles (10 microns and less) per cubic foot of air.	Weight of dust, mgs. per 100 cubic feet of air.
8151	Facing machine	17,500,000	264.0
8152	Edging machine	2,785,000	37.0
8153	.....do	3,702,000	72.0
8154	.....do	2,960,000	37.0
8161	Facing machine	7,515,000	179.0
8162	.....do	4,900,000	140.0
8163	.....do	1,869,000	118.0
8233	East end of room	202,000	18.0
8241	Center of room	9,910,000	81.0
8242	West end of room	1,135,000	17.0

Table V shows the results obtained in a similar workshop known as the new lathe room in which the aloxite wheels are finished to size. This is the room equipped with a system of exhaust ventilation of which the company was inclined to be proud.

The general impression of an observer on entering the room was, indeed, that it was much less dusty than the old lathe room. The results of our analysis, however, indicate that such was not the case. The optical impression of superiority was probably due to the better lighting, greater floor space, the newness of the room, to the lighter color of the dust, and, perhaps, to the fact that there were fewer very large particles present. The microscopic counts of samples collected here vary from 202,000 to 17,500,000 one-fourth standard unit particles per cubic foot of air, and weights per 100 cubic feet of air, from 17 to 264 mgs. The result of analysis of samples (samples 8233, 8241, 8242) taken at different points in the room, removed from machine

operations, show the air conditions here to be practically the same as those which existed in the old lathe room. Since it is the small dust particles which are the dangerous ones, we are of the opinion that the dust conditions in the new lathe room were not any better than those found in the old lathe room, despite the efforts that had been made at improvement. As a matter of fact the methods of dust removal in both these rooms were wholly inadequate. The suction head as measured in four cases varied from ¾ to 2¼ inches.

TABLE VI.—*Dust content of air, and weight of dust in mgs. per 100 cubic feet of air in the shaving room, factory B.*

Sample No.	Sampling position.	Total number of particles (10 microns and less) per cubic foot of air.	Weight of dust, mgs. per 100 cubic feet of air.
8191	Shaving machine	72,100,000	178.0
8192	.....do	181,000,000	662.0
8193	Facing machine	15,000,000	36.0
8194	.....do	15,950,000	47.0
8195	Shaving machine	176,500,000	397.0
8196	.....do	222,500,000	548.0

The next room studied was the shaving room, where, as pointed out above, the problem of dust control is of specially acute importance. Table VI shows our findings here. The weight of dust per 100 cubic feet of air varied from 36.0 to 662.0 mgs. The microscopic counts varied from 15,000,000 to 222,000,000 one-fourth standard unit particles per cubic foot. It is interesting to note that the highest weight and largest count of any obtained in the entire investigations were found in this room.

The impression one gets on watching the operation of shaving the wheels is that the dust produced is in the nature of large particles which should quickly fall to the ground. Our analyses show, however, that the number of small particles remaining in the air is greater here than in any of the other processes investigated. The dust removal methods as used in this room were wholly inadequate, as shown not only by the high dust counts and weights, but also by the determinations of air velocity at the hoods, made by the use of an anemometer, which showed readings between 500 and 700 feet per minute, an exceedingly low velocity for the proper removal of this dust. In addition, the hoods were faulty in design, in that the dust was not removed at the point of origin.

TABLE VII.—*Dust content of air, and weight of dust in mgs. per 100 cubic feet of air in the mixing room, factory B.*

Sample number.	Sampling position.	Number of particles (10 microns and less) per cubic foot of air.	Weight of dust, mgs. per 100 cubic feet of air.
8201	Basement	148,800,000	623.0
8202	do	53,500,000	149.0
8211	Coke grinder	12,260,000	262.0
8212	Near scales (first floor)	67,100,000	226.0

Table VII shows results of analyses in the mixing building, in which the coke is ground and the furnace mix is prepared. In addition, ferro-silicon brought from the furnace room is crushed here. Examination of the weights and counts obtained in this building again shows remarkably high figures. The weights varied from 149 to 623 mgs. per 100 cubic feet of air, and the counts varied from 12,200,000 to 148,800,000 one-fourth standard unit particles per cubic foot of air. The air in the basement, and at other points where samples were taken, was so full of dust that the field investigator, even though he wore a respirator during the sampling period, experienced great discomfort.

The gross pollution of the air in this building was due mainly to the failure to remove properly the dust at the coke crusher and at the ferro-silicon crusher; and also to the failure to repair breaks in the bucket elevators which lift the crushed material to the storage bins above.

TABLE VIII.—*Dust content of air, and weight of dust in mgs. per 100 cubic feet of air in the old grinding room, factory B.*

Sample number.	Sampling position.	Number of particles (10 microns and less) per cubic foot of air.	Weight of dust, mgs. per 100 cubic feet of air.
8213	Pan mill	584,000	....
8221	do	3,200,000	62.0
8222	Outdoors (gateway)	5,190,000	92.0
8223	Pan mill	8,290,000	105.0
8224	do	16,100,000	95.0
8225	Elevator	32,500,000	327.0
8226	Outdoors (yard)	2,915,000	24.0

Table VIII shows the result of our analyses in the so-called old grinding rooms in which the carborundum after being removed from the furnace is crushed in pan mills. These mills are loaded with large pieces of carborundum and during this operation (which takes about five minutes) the dust produced is most intense. The mills continue grinding for about 45 minutes and occasionally during this

period a small quantity of water is added. It seems quite certain that the amount of dust in the neighborhood of these mills could be greatly reduced if the process were made a wet one. This modification should not interfere with the steps which are to follow in the preparation of the finished product, because the very next procedure is that of washing the crushed material in a mixture of acids to free the carborundum from impurities.

A good illustration of the effect of leaky bucket elevators is shown in sample 8225. This sample, which was taken in close proximity to the elevator (adjacent to a worker), shows the highest count and weight of any sample in these rooms and in our opinion is due to faulty maintenance of the elevator shaft. This serious defect could very easily be remedied.

Two samples of air collected outdoors, but in close proximity to these grinding rooms, were taken to note the effect on the outdoor air and the results (samples 8222 and 8226) show this air to be grossly polluted.

Samples 8231 and 8232 (see Table III) were taken in the so-called new grinding room where the aloxite is prepared. The "new" grinding room, like the "new" lathe room, was supposed to be superior to the "old" one and had been equipped with elaborate inclosed machines designed to remove the dust. As a matter of fact, the general impression obtained by ocular observation was that this room was far less dusty than the old grinding room. Here, as in the case of the lathe rooms, ocular evidence appears to be deceptive, since the two samples collected in the new grinding room contained, respectively, 23,800,000 and 11,500,000 one-fourth standard unit particles per cubic foot of air and 563 and 290 mgs. of dust per 100 cubic feet of air.

To summarize the general conditions obtaining in this factory it may be pointed out that 38 air samples from the workrooms showed the following distribution of dust counts, only the one-fourth standard unit particles being considered:

Total of 38 samples.	Number of one-fourth standard unit particles per cubic foot of air.	Total of 38 samples.	Number of one-fourth standard unit particles per cubic foot of air.
2 samples	Under 1 million.	9 samples	10-50 millions.
3 samples	1-2 millions.	3 samples	50-100 millions.
7 samples	2-3 millions.	Do	100-200 millions.
4 samples	3-5 millions.	1 sample	Over 200 millions.
6 samples	5-10 millions.		

The weight of dust was as follows:

Total of 37 samples.	Mgs. of dust per 100 cubic feet of air.	Total of 37 samples.	Mgs. of dust per 100 cubic feet of air.
3 samples	0- 20.	2 samples	150- 200.
8 samples	20- 50.	6 samples	200- 400.
9 samples	50-100.	5 samples	400-1,000.
4 samples	100-150.		Over 1,000.

The average number of particles per cubic foot of air was 31,000,000 and the average weight was 1.74 mgs. per cubic foot of air or 174.0 mgs. per 100 cubic feet of air.

Of the seven highest dust counts from factory B (containing more than 50,000,000 dust particles per cubic foot), four were from the vicinity of the shaving machines and three from the mix room. Of the five greatest weights (over 400 mgs. per 100 cubic feet of air) two were from the shaving machines and one each from the lathe room, mix room, and grinding room.

For convenience of comparison, the figures cited by Higgins and Lanza for the Joplin mines (Bulletin 132, U. S. Bureau of Mines) have been converted over to the basis of weights in mgs. per 100 cubic feet of air. The Joplin figures classified in groups by weights, distribute themselves as follows:

Total of 221 samples.	Mgs. of dust per 100 cubic feet of air.	Total of 221 samples.	Mgs. of dust per 100 cubic feet of air.
32 samples	0-20.	12 samples	150-200.
67 samples	20-50.	10 samples	200-400.
63 samples	50-100.	3 samples	400-1,000.
30 samples	100-150.	4 samples	Over 1,000.

All samples considered, the conditions in factory B were worse than those found in the Joplin mines, as shown in the following summary, which gives a comparison of percentage distribution of dust weights:

Mgs. of dust per 100 cubic feet of air.	Per cent of samples, factory B (37 samples).	Per cent of samples, Joplin mines (221 samples).
0-20	8.1	14.5
20-50	21.6	30.3
50-100	24.3	28.5
100-150	10.8	13.6
150-200	5.4	5.4
200-400	16.2	4.5
400-1,000	13.6	1.4
Over 1,000	0.0	1.8

When one recalls Lanza's estimate that at least 30 per cent of the Joplin miners were suffering from industrial tuberculosis, it seems clear that the conditions existing in this abrasive factory constitute a grave menace to the health of the persons employed therein.

In addition to the 38 samples discussed above we collected 5 air samples in the offices of factory B and 5 out-of-doors in the immediate vicinity of the plant, in order to see how far the dust produced by the industrial processes was distributed beyond the workrooms immediately concerned. The results collected in Table IX show that the office air contained between 100,000 and 650,000 one-fourth standard unit particles per cubic foot, two of the samples being beyond the upper limit of 300,000 particles maintained in the polishing shops of factory A (described by Winslow, Greenburg, and Angermyer). The weight per 100 cubic feet of air ranged from 2.5 to 6 mgs. A control sample (No. 9061) for comparison with these office samples was collected in an office building in the center of the city and opposite the railroad station. It showed only 73,500 one-fourth standard unit particles per cubic foot and only 0.60 mgs. of dust per 100 cubic feet of air.

Of the 5 outdoor samples 4 were very satisfactory, but one contained over 2,000,000 one-fourth standard unit particles per cubic foot (55.90 mgs. per 100 cubic feet of air). This sample was taken near a dilapidated and leaking cyclone separator. The 4 good samples were taken on an unusually clear day and to leeward of the factory.

It seems clear from the results tabulated in Table IX that even the office workers and yard helpers in Factory B (many of whom are women) are exposed to serious dangers from industrial tuberculosis, as a result of the inadequate handling of the dust hazard in the production departments of this factory.

TABLE IX.—*Dust content of air in number of particles and weight in mgs. per cubic foot of air in offices and yards, factory B.*

Sample number.	Sampling position.	Number of particles per cubic foot of air, classified by size in standard units.			Total number of particles per cubic foot of air.	Standard units per cubic foot of air.	Weight of solids, mgs. per cubic foot of air.			Percentage of inorganic solids.
		10 Std. u.	1 Std. u.	¼ Std. u.			Total.	Organic.	Inorganic.	
8281	Research laboratory	......	6,815	270,200	277,000	74,600	0.06	0.01	0.05	83.4
8282	Works' office	566	17,580	114,800	132,900	51,960	.04	.01	.03	75.0
8283	.....do	208	10,630	195,000	205,800	207,700	.025	.005	.02	80.0
8284	Accounting office	208	14,400	651,000	665,600	179,200	.029	.017	.012	41.4
8285	Billing department	370	6,850	579,000	586,200	155,300	.034	.016	.018	53.0
9061	Down town building	......	1,600	73,500	75,100	20,000	.006	.005	.001	16.6
8286	Outdoors	1,668	44,200	2,325,000	2,370,800	642,100	.56	.142	.417	74.5
8271	.....do	185	1,480	120,000	121,600	33,300	.014	.005	.009	64.2
8272	.....do	......	926	142,000	142,900	36,400	.010	.001	.009	90.0
8273	.....do	......	4,070	59,100	63,100	18,800	.024	.014	.010	41.7
8274	.....do	......	1,850	38,850	40,700	11,500	.007	.001	.006	85.7

It may be of interest to note that the average size of the particles in the air of the workrooms of factory B was about 0.26 standard units and the weight 0.000000055 mg. The average particle in the polishing shops of factory A as reported by Winslow, Greenburg and Angermyer had a size of 0.28 standard units and weighed 0.000000086 mg. In other words the dust particles in the carborundum works were a little smaller and a little more than two-thirds as heavy as those found in the air of the polishing shops. The dust collected in factory B averaged 86.2 per cent inorganic material, but a considerable percentage of organic material was found in the mixing and grinding rooms.

The Dust Hazard in Abrasive Factory C.

At the second abrasive factory investigated (factory C) crude, abrasive material is made and shipped to another city, there to be manufactured into wheels. The process which we studied here consists of the manufacture of an abrasive material, alundum, by the fusing of precipitated aluminum hydroxide in an electric arc furnace, or by the fusing of bauxite with coke in the same manner.

The process as carried on at this plant consists in receiving the aluminum hydroxide in bags, emptying the bags, carting the material to bins on the furnace room floor by means of "buggies," shoveling the material into electric arc furnaces and then fusing it. At the close of the run, the "pig" is removed, cooled, broken into large pieces, crushed, and finally elevated to a storage bin, from which it is run into freight cars.

The industrial operations which give rise to the greatest quantity of dust are the crushing, furnacing, and coke grinding operations, each of which has been studied in detail (see Table X).

The furnacing and crushing operations are carried on in one room. In the furnacing operation the crude material is brought from a storage room to the furnace platform by means of "buggies" and is emptied into open bins before the furnaces, from which place it is shoveled into the furnaces themselves. The two chief sources of dust are the transferring of the material into these bins from the buggies and the shoveling into the furnaces.

Samples 8292 and 8301 were taken in this portion of the room and show weights of 119.9 and 185.7 mgs. of dust per 100 cubic feet of air and counts of 5,500,000 and 13,500,000 one-fourth standard unit particles respectively.

In the crushing operation the fused material from the furnace is crushed and carried by means of a belt conveyor to an elevator shaft and then lifted to a storage bin above. Seated alongside the conveyor is a group of women whose duty it is to remove from the product any impurities which may be found therein. The task of

another female worker, seated alongside the crusher, is to keep the material, as it leaves the crusher, from piling up in one place and thus obstructing the elevator. It was in this operator's position that sample 8294 was taken. Analysis of this sample showed the exceedingly high count of 311,000,000 particles and the second highest weight of any obtained in our study, 2,139 mgs. per 100 cubic feet of air.

TABLE X.—*Dust content of air in number of particles and weight in mgs. per cubic foot of air, various locations, factory C.*

Sample number.	Sampling position.	Number of particles per cubic foot of air, classified by size in standard units.			Total number of particles per cubic foot of air.	Standard units per cubic foot of air.	Weight of solids, mgs. per cubic foot of air.			Per cent of inorganic solids.
		10 Std. u.	1 Std. u.	¼ Std. u.			Total.	Organic.	Inorganic.	
	Grinding room:									
8291	Sorting belt	......	133,500	17,110,000	17,143,500	4,411,000	2.978	0.038	2.94	98.9
8292	Furnace level	......	139,000	5,500,000	5,639,000	1,514,000	1.199	.021	1.178	98.2
8293	Sorting belt	......	504,000	20,660,000	21,164,000	5,669,000	4.209	.044	4.165	98.9
8294	Bucket elevator	......	3,320,000	311,000,000	313,320,000	81,070,000	21.39	.210	21.18	99.0
8295	West end of room	......	103,800	4,320,000	4,423,800	1,183,800	.749	.018	.731	97.7
	Furnace room:									
8301	Mix bin	......	488,000	13,550,000	14,038,000	3,875,500	1.857	.051	1.806	97.4
8302	Storage bin	......	1,067,000	62,900,000	63,967,000	16,792,000	7.699	.259	7.44	96.7
8303	Coke-grinding room	87,000	10,880,000	669,000,000	679,880,000	179,000,000	21.50	6.35	15.15	70.4
8304	Corridor	......	2,440,000	316,000,000	318,440,000	81,440,000	8.66	5.92	2.74	31.6
	Outdoors:									
8296	Street near plant	......	51,800	851,000	902,800	264,600	.127	.016	.111	87.5
8297	200 feet distant	......	13,030	126,800	139,800	44,700	.051	.019	.032	62.7
9031	¼ mile distant	......	4,620	310,000	314,600	82,100	.016	.005	.011	68.7
9043	Yard	......	591	145,800	146,400	37,000	.065	.013	.052	80.0
9062	Residential district	355	533	33,950	34,800	12,600	.005	.003	.002	40.0
9063	Same as 9031	......	1,776	60,400	62,200	16,900	.005	.002	.003	60.0
9041	Research laboratory	......	1,970	537,600	539,600	136,400	.013	.007	.006	46.1
9042	Superintendent's office	......	197	89,200	89,400	22,500	.008	.001	.007	87.4

Two other samples, 8291 and 8293, were taken at points alongside the conveyor at distances of 12 feet and 18 feet from the crusher. These samples also show exceedingly high counts and weights, 17,110,000 and 20,660,000 one-fourth standard unit particles per cubic foot of air, and 297.8 and 420.9 mgs. of dust per 100 cubic feet of air, respectively.

One sample, 8295, of air taken in the west end of the room about 20 feet from the crusher shows a count of 4,320,000 particles and 74.9 mgs. of dust per 100 cubic feet of air.

In the coke-grinding operation, coke, to be used in the manufacture of alundum from bauxite, is shoveled into a crusher and broken down into fine pieces which are carried to a bin above by means of a bucket elevator. The results of the dust analyses of air taken in this part of the plant are shown in the table as samples 8303 and 8304. Number 8303 was taken in the room proper, whereas 8304 was taken in the corridor alongside the room. Sample 8303 shows a dust count of 669,000,000 one-fourth standard unit particles per

cubic foot of air, and a weight of 2,150 mgs. of dust per 100 cubic feet of air, the count and weight in this case being the highest in either plant studied. Sample 8304 shows a count of 316,000,000 one-fourth standard unit particles per cubic foot of air, and a weight of 866 mgs. per 100 cubic feet of air.

Of nine samples of air collected in production departments of the plant, all contained over 1,000,000 one-fourth standard unit particles per cubic foot, and three more than 100,000,000. Of these nine samples all contained over 28.3 mgs. of dust per 100 cubic feet of air. (The standard set by Higgins, Lanza, and others for the Joplin mines is 1 mg. per 100 liters, or 28.3 mgs. per 100 cubic feet.)

In the lower part of Table X are shown the results of analyses of two air samples from the offices in factory C, five outdoor samples in the vicinity, and one control outdoor sample from a residential district of the city. Of the office samples, one collected in the Research Laboratory contained 537,600 one-fourth standard unit particles per cubic foot of air. More significant, however, are the outdoor samples Nos. 8296, 8297, and 9031. The first, collected on the street close to the plant, showed 0.127 mg. of dust per cubic foot. The second was collected about 200 feet farther away, but in the direction in which the wind was blowing the dust from the ventilating stacks over the electric arc furnaces, and showed 0.051 mg. The third sample was taken a quarter of a mile away; but the cloud of dust from the stacks was clearly visible even at this point, and the presence of 0.016 mg. of dust showed appreciable pollution. Sample 9063 taken at the same point as 9031 when the wind was in a different direction, and sample 9062, collected in a residential district free from special pollution, show that the normal dust content of the air at this season was only 0.005 mg. per cubic foot.

The amount of dust present in the air of this plant could be greatly reduced by properly inclosing the crusher, by improved methods of handling and transferring the crude material to the furnaces, and by means of a well-designed hood over the coke crusher.

Comparison of Dust Content of Air in Abrasive Factories with that Reported for Other Industrial Establishments.

It may be interesting to compare these results with those reported for various industries by Miller and Smyth (Journal of the American Medical Association LXX, 599). We have tabulated in Table XI their principal data in comparison with our own and with those obtained by Higgins and Lanza in the Joplin mines.

TABLE XI.—*A comparison of data pertaining to dust content of air in different industries.*

Industry.	Observer.	Number of samples.	Dust particles per cubic foot.	Mgs. dust per 100 cubic feet.	Percentage of inorganic solids.
Good polishing shop	Winslow, Greenburg, and Angermyer.	15	207,000	2.37	77
Cigar shops	Miller and Smyth	19	102,600	8.4	56
Pottery	do	5	182,720	13.0	60
Asbestos	do	6	494,100	35.4	73
Steel grinding	do	3	489,930	43.3	96
Flint	do	3	844,040	45.9	76
Blanket, plush, and carpet	do	13	148,950	50.4	44
Joplin mines	Higgins, Lanza, et al.	221		146.4	
Abrasive factory "B"	Winslow, Greenburg, and Greenberg.	57	31,010,000	174.3	86
Cement mill	Miller and Smyth	11	6,790,900	218.5	72
Abrasive factory "C"	Winslow, Greenburg, and Greenberg.	9	159,779,000	780.5	87

It will be noted that our figures for factory B are somewhat in excess of those found by Higgins and Lanza for the Joplin mines; and the figures for factory C are greatly in excess of any reported, including the cement mill studied by Miller and Smyth.

It seems obvious from these results that establishments devoted to the manufacture of abrasive materials may present conditions in regard to aerial dust content that can scarcely be equaled in any other industry. The study of such conditions and the devising of adequate means for so controlling them as to protect the workers in this trade from the menace of tuberculosis would seem to invite serious attention.

A DISPOSAL STATION FOR A CAN PRIVY SYSTEM.

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The method of ultimate disposal of the human excrement collected from a can privy system is undoubtedly a matter requiring most careful consideration. An improperly located disposal station, by reason of objectionable odors, will certainly become a source of complaint on the part of persons residing in its vicinity; and since a sanitary system of this character is frequently judged by such an objectionable feature, a malodorous disposal station might cause the condemnation of an otherwise adequate and effective system.

Fully as important as a suitable location is the proper equipment and management of the disposal station. When the sense of smell is offended, or hands and clothing of employees are soiled, it can not be expected that the attendants necessary to operate the station will remain. The disposal plant at Montgomery, Ala., represents the